PROPOSAL TO DEVELOP A CONCEPTUAL DESIGN FOR A NEXT-GENERATION LANDSAT

Introduction

To develop a next-generation LANDSAT instrument quickly and effectively, it will be necessary to take advantage of technology and techniques that are available "off-the-shelf". Much of the work that has been done in the past few years in developing hyperspectral technologies makes this feasible. This paper seeks to investigate the possibility to use currently available technologies innovatively, to quickly develop a next-generation LANDSAT instrument.

While the mere mention of "hyperspectral" makes many people skeptical, I would like to try to demonstrate that a properly conceived hyperspectral system could not only replace the current LANDSAT technology, but significantly improve the performance and lower the cost of the instrument. These improvements could be made with no additional demands placed on data transmission and processing systems. The key characteristic of a hyperspectral LANDSAT (HLS) is simplicity. The HLS would have no moving parts, and many fewer component parts than the current LANDSAT. It is well known that simplicity is the key to space-borne instrument reliability and cost saving. It should also be noted that the HLS concept is a full system design. By considering all aspects of the system design it will be possible to address "bottlenecks" that have traditionally caused problems.

Background

Since working on the MODIS-T conceptual design at the beginning of the EOS Project, I have been involved with various aspects of hyperspectral technology. If the conceptual design that I developed would have been used, the MODIS-T instrument would have been the first space-borne hyperspectral instrument. When this project failed, I took advantage of Goddard's Research and Study Fellowship program and went to Finland for a year where I initiated the development of an airborne hyperspectral imaging system. At the end of the one year Fellowship, the airborne instrument was complete and performing well. The Finnish developers of the instrument came to Goddard to support me in presenting the work that we had done. I had expected that Goddard management would be interested in the utilization and further development of this technology, but I was wrong.

Since then I have maintained an active interest in hyperspectral even though, with the exception of the EO-1 pathfinder mission, very little work has been done by NASA. Fortunately, people around the world have been pursuing hyperspectral and currently the technologies, if not the applications, are quite well developed. I propose to utilize these developments to generate a conceptual design for a next-generation or hyperspectral LANDSAT (HLS).

The Plan

To generate a conceptual design for the HLS a paper design trade-off study would first be done. This study would take the LANDSAT requirements and generate a “strawman” instrument design. This strawman design would then be analyzed and optimized. The design would be based on, but not limited to, the development work that I have done over the past several years. This general work is summarized in somewhat fragmentary fashion on the CARSTAD web pages at: http://carstad.gsfc.nasa.gov/topics/JBResProj.htm and more details of the proposed HLS (or HSSRRSI) can be found at: http://carstad.gsfc.nasa.gov/Topics/HSSRProject.htm.

Though Goddard has an in-house instrument conceptual design capability (the ISAL) I do not believe that the resources of the ISAL would be adequate to take on this task. A better alternative would probably be Swales. One reason for this is that many of the Swales staff have contacts outside NASA, namely in the defense community, who are active in the development of hyperspectral systems. It would not be at all surprising if Swales were very receptive to the idea of designing a hyperspectral remote sensing system. If a suitable design team could be assembled, it would not take more than a few months to come up with a thoroughly analyzed conceptual design. This thorough analysis would include both the theoretical analysis of the design as well as the study of available components.

As mentioned above, the key to success in the HLS is simplicity. The goal of the design study would not only be to replicate the capabilities of the current LANDSAT instrument, but to enhance the capabilities so that the information obtained from the instrument is easier for researchers to use. “Easier to use” means that less re-processing of the information is needed before the researchers can use the information for scientific purposes. Among the key factors for performance enhancement are:

- a seamless data stream (pushbroom with “bow-tie” correction)
- real-time 3-D data compression
- long term instrument response stability
- multiple, multiplexed focal planes
- embedded instrument calibration
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Unlike the current LANDSAT, the HLS would not have preset bands. Though it is possible to program a hyperspectral imager to simulate the bands of the LANDSAT instrument, this practice is counterproductive. The HLS would produce continuous spectra. These spectra would be transmitted to the researchers who could then, if they wish, extract the traditional LANDSAT bands.

The Essential Components

The technology essential to building the HLS includes all-reflective fore-optics, replicated optics spectrometers, megapixel high dynamic range array detectors, and high speed digital image processors. All of the required technology is currently available. The key to building the HLS is innovative application of the technology.

The all-reflective fore optics is essential for high throughput of the complete wavelength range. An innovative design of the fore-optics will provide a flat field-of-view (projecting the curved Earth onto a flat detector plane), and will eliminate the aberrations found in refractive systems.

One of the primary objections to a typical hyperspectral system is the large data rate and volume. This problem occurs because hyperspectral systems are being treated as multi-spectral systems with many bands. If, instead of transmitting the data byte-by-byte it were transmitted as spectral curves and as scenes, the data volume could be reduced dramatically. This capability has been demonstrated in lossy, and lossless, 3-D data compression technologies developed for other applications, but perfectly suited to a hyperspectral system.

To simplify construction of the HLS subsystem, modules would be used. For example, instead of attempting to build a single focal plane that will cover the entire swath, and the entire spectral range, the swath and the spectral range would be segmented and a separate focal plane used for each spectral and spatial portion. This will allow "off-the-shelf" components (spectrometers, detector arrays, and digital image processors) to be used and will decrease the acquisition and processing requirements by splitting the data stream among many sub-systems.

Follow-On Activities

The first step after successful completion of the conceptual design study would be to build a laboratory prototype of the HLS. Some components of the flight model HLS could be omitted from the laboratory model such as the full field-of-view fore optics and the full complement of focal planes.

Once the laboratory model was successfully built and thoroughly tested, an airborne version of the HLS should be built. This airborne instrument would be, for all practical purposes, an engineering model of the flight HLS. A rigorous campaign of airborne testing would not only prove the capability of the instrument, it would also provide the opportunity to collect useful remotely sensed information.

Conclusions

A conceptual design for a follow-on LANDSAT mission could be done quickly and effectively by making use of technologies available off-the-shelf. The primary requirements for a successful design are simplicity and innovation, and an experienced design team.